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METALS CONCENTRATIONS IN THE CLAYPIT POND AREA, WHATCOM COUNTY, WASHINGTON

Part 1
Metals Concentrations in Sediments of Claypit Pond Area Including a Review of Metals Levels Found in Water Samples

Part 2
Metals Concentrations in Fish Caught in Claypit Pond

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Part 1
Metals Concentrations in Sediments of Claypit Pond Area Including a Review of Metals Levels Found in Water Samples

ABSTRACT

Since 1980, metals concentrations in water and sediments in the Claypit Pond vicinity in Whatcom County, Washington, have been found to intermittently exceed background concentrations. One potential nearby source is a municipal-sized incinerator and ash dump. To gain an understanding of contemporary as well as historical heavy metal levels in the Claypit Pond, sediments were sampled for heavy metals in June 1988. Concentrations of copper, chromium, and zinc in sediments in Claypit Pond and the associated drainages are significantly elevated with respect to nearby reference areas. Copper concentrations range from 25 to 99 ppm (dry weight), chromium 69 to 740 ppm, and zinc 72 to 813 ppm. Concentrations of arsenic, nickel, and mercury were also examined. Compared with other freshwater and marine environments, chromium concentrations are very high. Even after some of the potential confounding effects of variations in overall surface area of sediments (measured by percent clay and percent total organic carbon) are accounted for, the concentrations of chromium in sediments near Claypit Pond are still substantially above those from reference areas. The potential biological effects of these high concentrations of metals in sediments should be evaluated through measurements of benthic infaunal diversity and bioassay responses to sediments. Collection and analysis of sediment cores from the pond may help to determine how contemporary metals sources compare with historical contaminant loads.

BACKGROUND

Heavy metal contamination is a concern in Claypit Pond, a small (11 acre) lake located 200 feet directly downstream from the Thermal Reduction Company (TRC), a municipal-scale incineration facility in Whatcom County. Ash from incineration is deposited on-site. Claypit Pond was the site of an inferred fish kill in 1979 (an age class of fish was missing from a sample taken in 1980) and relatively high heavy metal concentrations in water (Kittle 1980). These problems were mitigated by the installation of a leachate interceptor in 1981, and much of the runoff from the site is now piped to the Ferndale sewage treatment plant. In 1988, due to reports of high concentrations of metals at one site in waters upstream from Claypit Pond (Douglas, 1987), the Washington Department of Wildlife (the owner of Claypit Pond) closed the pond to all fishing. Semivolatile organic priority pollutants from sediments near Claypit Pond were also examined and in one of two sediment samples only 0.4 ppm high molecular weight polyaromatic hydrocarbons were found (Douglas, 1987). At the request of the Northwest Regional Office (NWRO) of the Department of Ecology, the Toxics Investigation Section conducted a study of metals contamination in the Claypit Pond drainage focusing on sediment and fish tissue (see Part 2 of this report for results of fish tissue study).

To provide background on metals concentrations in waters in and around Claypit Pond, I have summarized several different studies conducted by the Department of Ecology since 1980. Figure 1 shows the study site and general locations of historical samples. The study

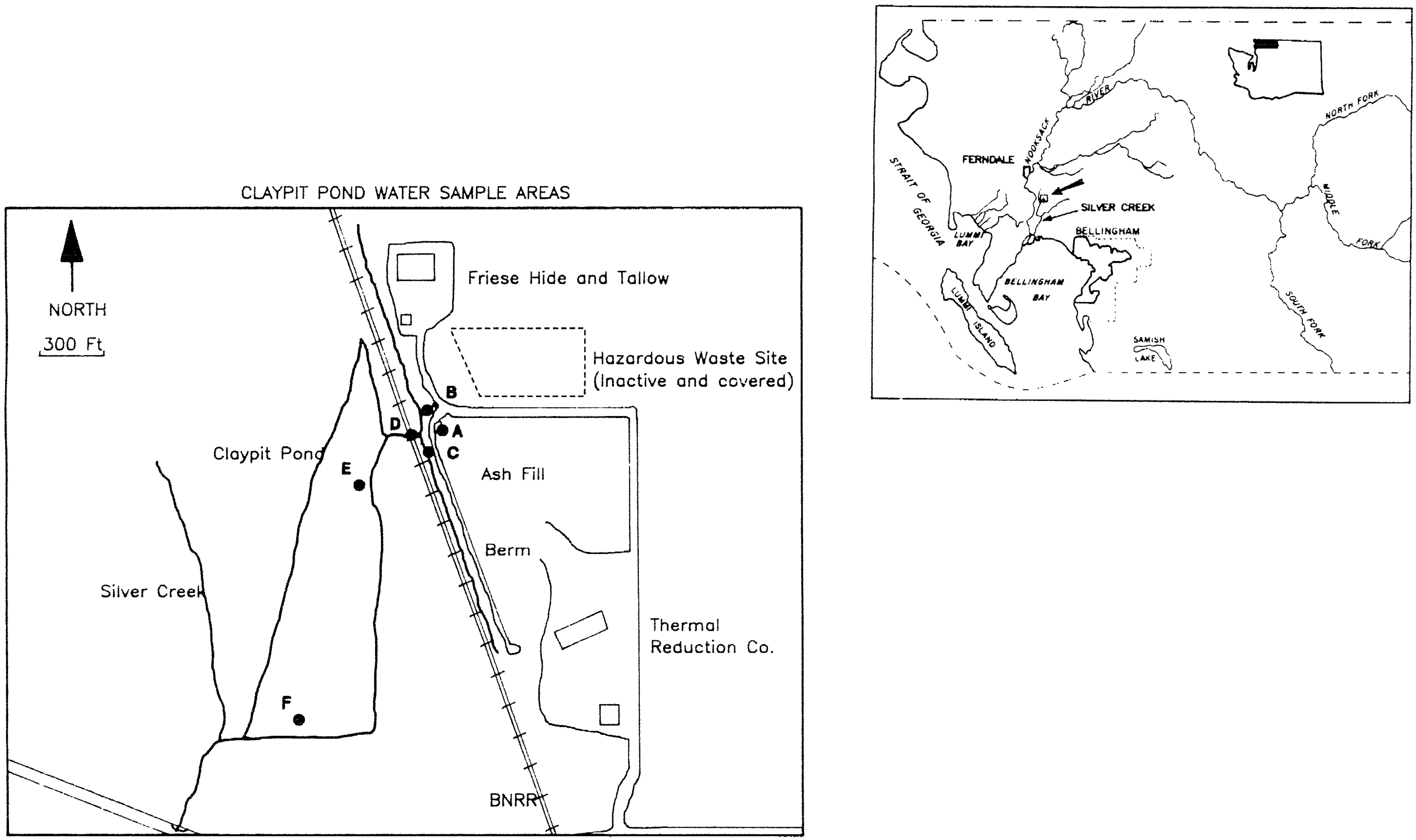


Figure 1. Location of study areas showing where past water quality samples were taken.

area consists of Claypit Pond and the associated inlet and outlet drainages and is located about two miles southeast of the city of Ferndale in Whatcom County, Washington. The pond itself was created by quarrying clay for bricks. The current depth of the pond is a maximum of about 30 feet, and its surface area is 11 acres. The sole surface water source of the pond is a creek that flows from the east side of the railroad tracks through a culvert. In the drainage of this stream are Friese Hide and Tallow and TRC. Included in TRC's site are an incinerator, ash disposal dump, and a hazardous waste disposal site just north of the ash pile that was covered in 1981. Additional site background appears in Douglas (1987).

Table 1 shows surface water concentrations of three metals (chromium, nickel, and copper) found in various studies. Sites E and F are in Claypit Pond, and since 1986 show near-background concentrations of all three contaminants (Chromium, 1-2 ppb; Nickel, 1-3 ppb; Copper, 0.5-1 ppb; Moore and Ramamoorthy 1984). These levels are below EPA "chronic" criteria (EPA 1986a). Higher metals concentrations are seen consistently in the leachate collection pond (Site A) and the outfall from the inactive hazardous waste site (Site B). The outfall from this waste site drains through Site D (the culvert under railroad tracks) and empties into the pond. Figure 2 graphs the decline in chromium levels in surface waters found from 1980 to 1988 at sites D and F. Anomolously high concentrations were measured at site C (outside berm) in October 1986. These concentrations are higher than the leachate collection pond levels reported for 1986 and were not found in the June 1987 or March 1988 sampling of the same area conducted by NWRO. The inability to reproduce those high levels suggests either an error in the October 1986 sampling or analysis, or a highly intermittent source of contamination. To gain a better understanding of contemporary as well as historical heavy metal levels in the Claypit Pond, sediments were sampled for heavy metals in June, 1988. Levels of contaminants found in fish are reported in Part 2 of this report.

METHODS

Sampling methods

Figure 3 shows locations of ten sampling stations in the study area. Two additional sampling sites are south of the area shown on this map and are downstream along Silver Creek. All samples were taken on June 9, 1988. Sediments in rivers and streams were sampled with a hand-held Emery pipe dredge or stainless steel scoops. Bottom sediments in Claypit Pond were sampled using a stainless steel Ponar hand grab from a rowboat. Positions in the pond were determined from range measurements to landmarks. The top 0-4 inches of sediments in the grab were scooped with a stainless steel spoon into a stainless steel beaker, thoroughly mixed, and a subsample filled into jars. All samples were stored in metals clean glass jars (I-Chem series 300), cooled with ice within one hour, and frozen within 12 hours of sampling. The dredge used at sites 12 and 13 was washed and nitric acid rinsed between grabs. The hand grab, used at the Claypit Pond sites was rinsed between grabs. All scoops, beakers, and spoons were washed, rinsed serially with acid and deionized water, and covered with aluminum foil prior to field sampling. They were used only once in the field. To

Table 1. Levels of selected heavy metals in surface water (ug/l) near the Thermal Reduction Incinerator and Landfill in Ferndale, WA. See accompanying figure for site locations.

Site[1]		Month - Year 2/80[2]	5/80[3]	3/81[4]	10/86[5]	6/87[6]	6/87[7]	1/88[8]	2/88[9]	3/88[10]
					Chromium (EPA Water quality criteria = 207)[11]					
A	Leach collec.	-	-	-	22	57	60	-	56	-
B	From Haz pit	-	-	-	42	-	-	150	-	180
C	Outside berm	-	-	-	1083	21	-	-	-	21
D	RR Culvert	483	80	10	-	-	-	18	10	7
E	In pond	-	200	40	-	-	-	-	-	4
F	Out pond	137	200	60	2	-	-	-	-	4
	Leachate		7200	3100		601				
					Nickel (EPA Water quality criteria = 158)					
A	Leach collec.	-	-	-	10	5	16	-	52	-
B	From Haz pit	-	-	-	18	-	-	160	-	100
C	Outside berm	-	-	-	403	5	-	-	-	1
D	RR Culvert	24	-	-	-	-	-	5	34	2
E	In pond	-	-	-	-	-	-	-	-	2
F	Out pond	11	-	-	<5	-	-	-	-	1
	Leachate					104				
					Copper (EPA Water quality criteria = 11.8)					
A	Leach collec.	-	-	-	<1	26	27	41	-	-
B	From Haz pit	-	-	-	10	-	-	-	59	60
C	Outside berm	-	-	-	742	7	-	-	9	-
D	RR Culvert	23	-	-	-	-	-	<3	2	6
E	In pond	-	-	-	-	-	-	-	2	-
F	Out pond	11	-	-	<1	-	-	-	3	-
	Leachate					25				

[1] See accompanying figure for site locations.
[2] EPA survey; From Northwest Regional Office (NWRO) Dept. of Ecology files, Redmond, WA.
[3] Memo from Lew Kittle to Bob McCormick in NWRO files, Redmond, WA.
[4] Survey by Lew Kittle (NWRO) Redmond, WA.
[5] Site inspection report, Thermal Reduction Company, Ferndale, WA by Hector Douglas, Hazardous Waste Cleanup Program (HWCP) Dept. of Ecology, Olympia, 1987.
[6] Survey by John Glynn (NWRO) reported in Douglas (1987)
[7] Survey by Dave Garland (NWRO) reported in Douglas (1987)
[8] From sampling by Lori Levander (NWRO)
[9] From Class II inspection (site A) and letter to Dave Bader from Dave Garland NWRO files.
[10] From sampling by Kevin Fitzpatrick (NWRO)
[11] From EPA Quality Criteria for Water 1986 for hardness of 100. "Chronic" criteria.

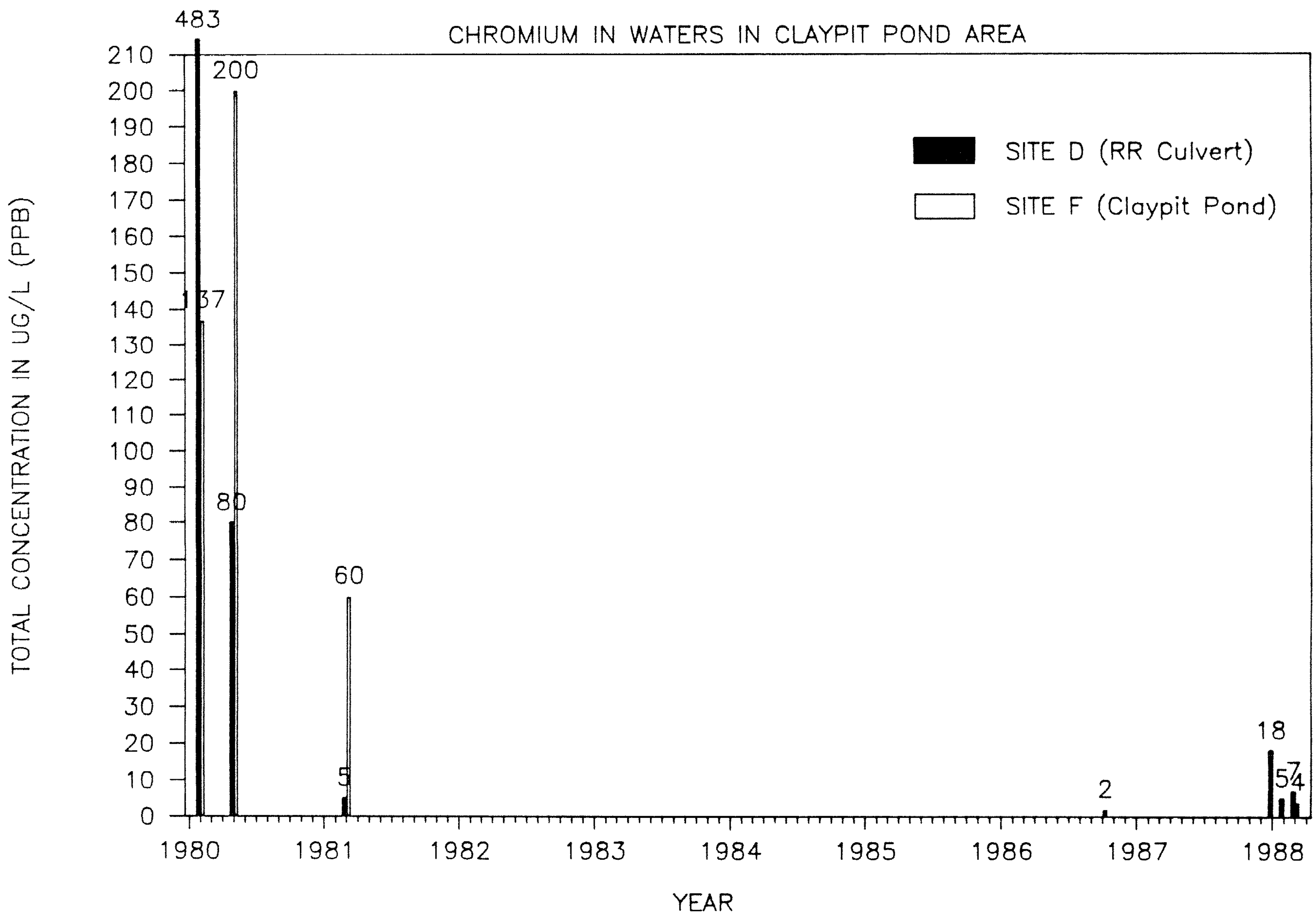


Figure 2. Historical trend in chromium levels in Claypit Pond vicinity. Site letters refer to Figure 1 and Table 1.

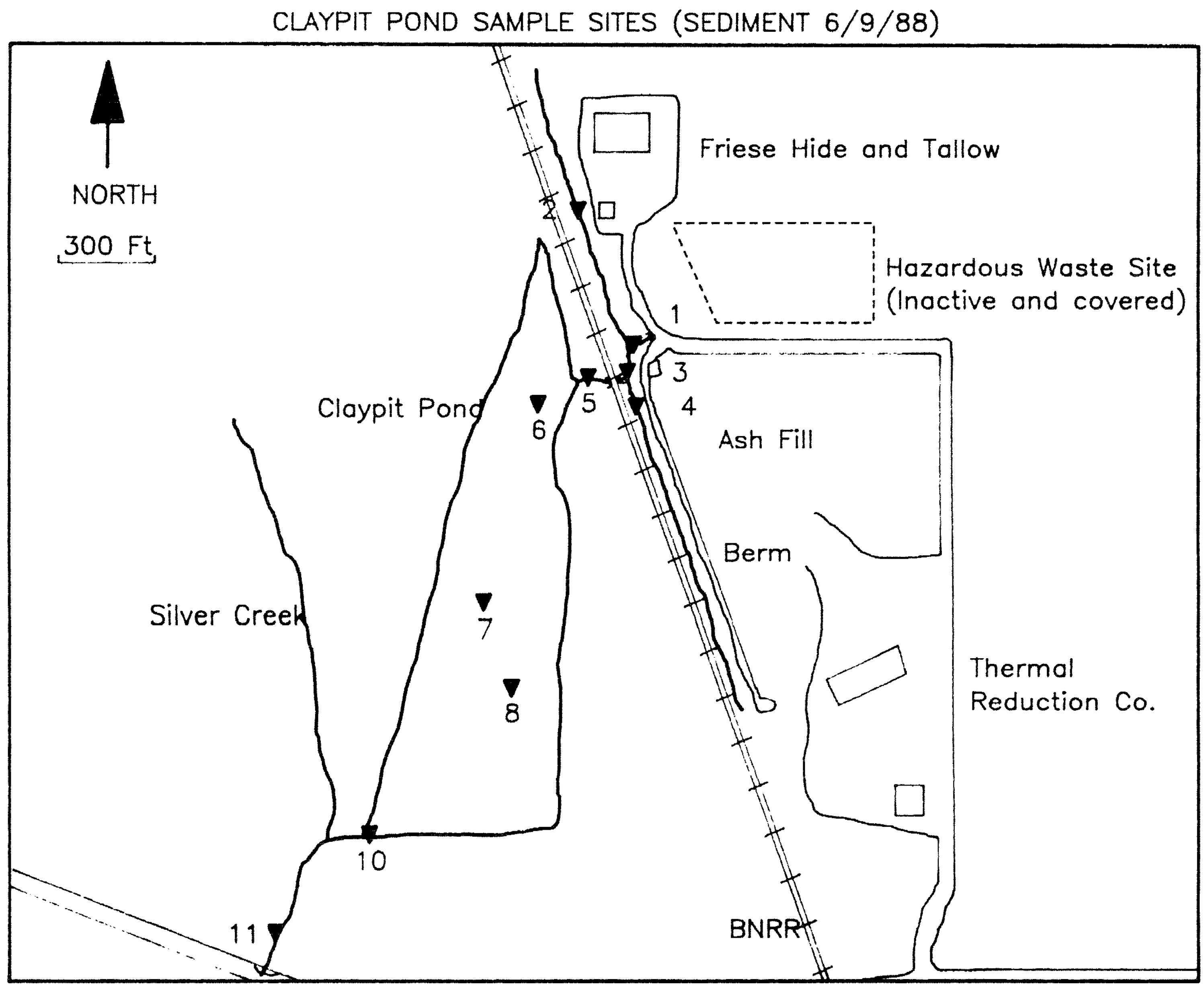


Figure 3. Map of study area showing locations of sediment sampling stations near Claypit Pond. Two additional samples were taken south of the study area along Silver Creek. All samples were taken on June 9, 1988. Map derived from 1987 aerial photographs.

minimize cross-contamination, sampling was conducted from Site 13 to Site 1 in the direction of anticipated increase in contamination.

Physical/Chemical Analysis

Samples were analyzed at the Department of Ecology/EPA Manchester laboratory for metals concentrations. Sediment samples were digested using nitric acid and hydrogen peroxide as specified by EPA method 3050 (EPA, 1986). Cadmium, chromium, lead, nickel, and zinc were analyzed on inductively coupled plasma spectrophotometer using EPA method 200.7 (EPA, 1982). Arsenic and mercury were analyzed on an atomic absorption spectrophotometer using methods 206.5 and 245.5 (EPA 1979), respectively. All results are reported on a dry-weight basis. Measurements of total organic carbon with persulfate-UV (method 505, APHA 1985) and grain size (method of sieves and pipettes, Holme and McIntyre 1971) were conducted by Lauck's Laboratories in Seattle, Washington.

Data Interpretation

Concentrations of metals recorded in sediments collected during this study were compared with levels found in other areas in Whatcom County. Figure 4 depicts locations of other areas near the Claypit Pond site where metals concentrations have been measured in sediments. Results are segregated into three areas--"On-site," "Downstream," and "Reference." The "On-site" area refers to sites shown in Figure 3 except for site 11. The "Downstream" area includes locations on Silver Creek downstream from Claypit Pond. The "Reference" area includes sites that are not downstream of the drainage of Claypit Pond but are located within the county.

Statistical tests for variance between these sites were performed with the non-parametric Kruskal-Wallis test (Zar, 1974) (data failed tests of normality--an assumption of standard parametric statistical tests). Standard linear correlation tests were also performed to test for effects on metals concentrations of variations in percent clay and percent TOC.

Quality Assurance

To determine precision and, to some degree, accuracy of the analytical methods, one sediment sample was divided into three subsamples. Two of these subsamples were spiked in the laboratory with known concentrations of target metals, and analyzed. In addition, another sample was homogenized and split in the field. This sample was then placed in two jars, labeled separately, and submitted to the laboratory as a blind duplicate.

Table 2 reviews tests of precision and accuracy of analytical methods. Relative percent difference (RPD: the difference between two samples divided by the mean of the samples) of the blind and spiked duplicate samples was used to assess precision. For both the blind replicates and the spiked samples, the RPD's are acceptably low (1-18%) for all metals.

SEDIMENT SAMPLES NEAR CLAYPIT POND

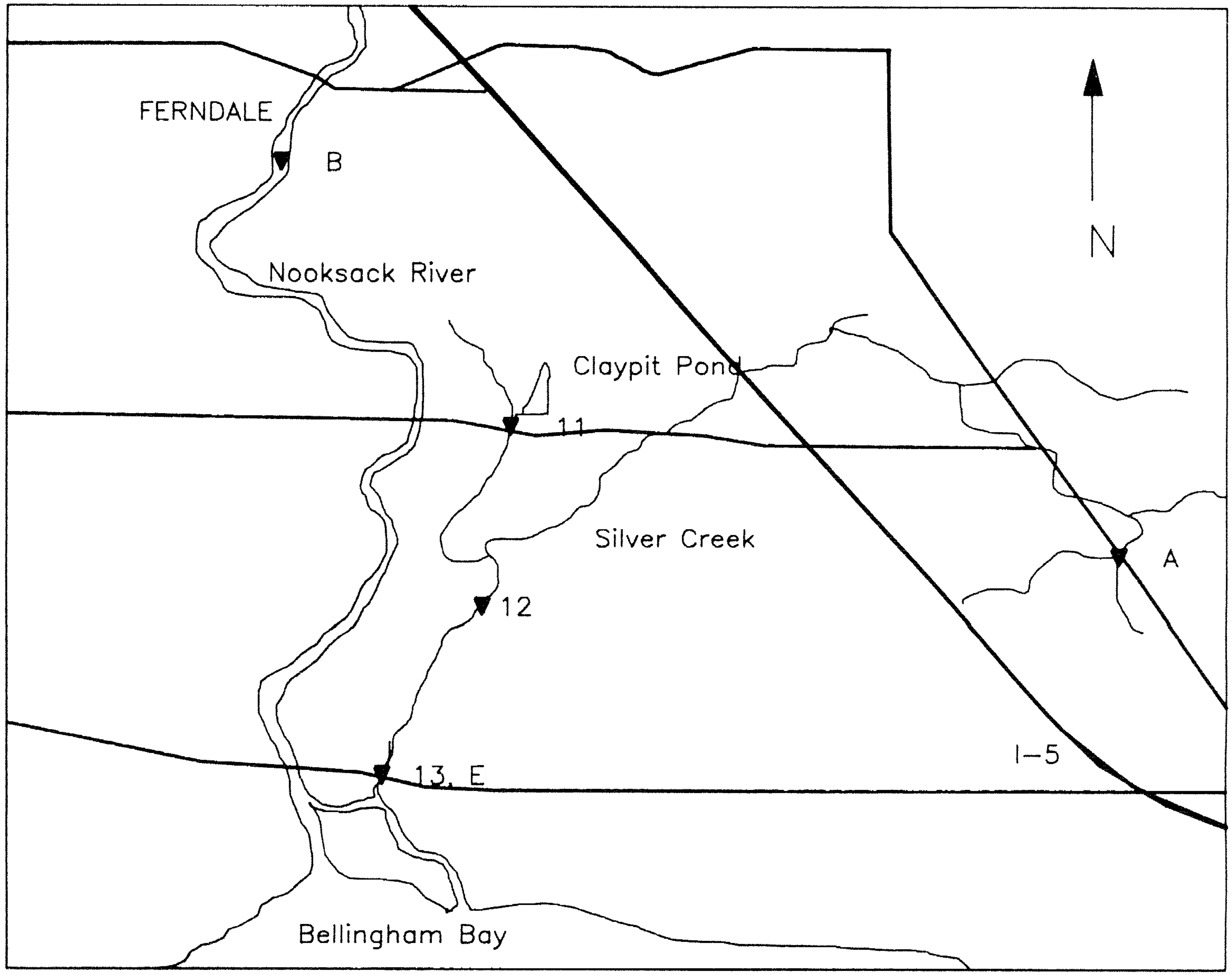


Figure 4. Map of portion of Whatcom County with sediment sampling sites from this study (11, 12, 13) and other studies (see text). Sampling sites on Whatcom Creek in Bellingham just SE of map are not shown. Sites 11, 12, 13, and E form a set of samples from "Downstream" area. Sites B, A, and Whatcom Creek sites form a "Reference" pool of sites.

Table 2. Measurements of precision and accuracy of analysis of sediments in the Claypit Pond area for metals.

Location	Sample Number	As	Cd	Cr	Cu	Pb	Ni	Hg	Zn
		Metal							
Blind split replicate		Units - ug/g dry wt.							
Site 8	8	7.6	ND[1]	98	41	ND	66	0.036	119
Site 8	9	7.2	ND	102	47	ND	63	0.043	110
RPD[2]		5%		4%	14%		5%	18%	8%
Spike Duplicate		Units - % recovery							
Site 11 average		79%	94%	97%	105%	77%	97%	108%	92%
RPD		6%	3%	8%	1%	3%	5%	3%	7%

[1] ND = None detected
[2] RPD = Relative percent difference [(S1-S2)/((S1+S2)/2)] X 100 where S1 and S2 are replicate analyses.

EPA's Contract Lab Program (CLP) requires that RPDs for metals in sediment not exceed 25% (EPA 1986c). Recovery of metals from spiked samples was acceptable. Recoveries ranged from 77 to 108% which are within EPA Contract Laboratory Program limits of 75% to 125% (EPA 1986c).

RESULTS AND DISCUSSION

Concentrations on Site

Table 3 shows metals concentrations found in Claypit Pond area sediments. All Concentrations are reported on a dry weight basis. Figures 5 through 9 show concentrations by location in the Claypit Pond area. Of particular note are the high concentrations of arsenic, chromium, and zinc found in sites 3 and 4. These high concentrations found at sites 3 and 4 prompted re-extractions and analysis of these two sediment samples. Table 4 shows the results of these comparisons. Overall, the two analyses show comparable concentrations and thus tend to verify the high concentrations reported at sites 3 and 4. Two exceptions to good reproducability are cadmium and lead. The reanalysis of cadmium showed concentrations an order of magnitude higher than the detection limit on the previous analysis. Similar problems appeared for lead. Although cadmium and lead were found above detection limits at only one site during the initial analyses, I have removed cadmium and lead from the list of metals examined due to poor consistency in the results for these two metals. Because sample holding time was exceeded for the reanalyses and to preserve comparisons between samples, I have used only the initial analytical results in the rest of the report.

Percent fine grain (clay) material and percent TOC affect the concentrations of metals that can sorb to sediments (Schultz *et al.*, 1987). Correlations between these qualities and metals concentrations are reviewed by Horowitz (1984). Figure 10 shows grain size characteristics for sediments taken. No significant ($p < 0.05$) correlation was found between concentrations of any metals and percent clay (<4um) in the sediments except for copper (see Table 5). Correlations were found between percent TOC and concentrations of arsenic, copper, mercury and zinc ($p < 0.05$), but these correlations were entirely dependent on the highest two TOC values for their significance (sites 3 and 4). If these two were removed from consideration, no significant correlations exist (Table 5). Because of the undue influence the sites with high TOC levels exerted (sites 3 and 4), I decided it was not appropriate to correct these levels for TOC. However, the high metals concentrations found in sediments at sites 3 and 4 may be linked to the high levels of organic carbon at those sites.

Metals Concentrations Compared to Sediments at Other Locations

Whatcom County - Table 6 compares concentrations found in this study with levels found in Whatcom County in other studies. Geometric mean concentrations of chromium, copper, and zinc are higher Onsite than Downstream or at the Reference sites. Table 7 reviews

Table 3. Percent clay (grain size 4 um), percent total organic carbon (TOC), and metals concentrations in sediment (ug/g dry weight) at study area sites.

Site #	Description	% Clay	% TOC	As	Cr	Cu	Hg	Ni	Zn
1	Haz. waste drainage	0.4	0.4	2.6	98	25	0.040	54	72
2	Freise Hide & Tallow	18.9	0.6	9.9	75	69	0.035	71	128
3	Confl. before culvert	25.7	6.9	17.9	740	52	0.060	59	347
4	Stream outside berm	47.4	11.0	23.6	201	99	0.067	151	813
5	Stream feeding pond	23.6	1.4	1.9	74	30	0.027	43	104
6	Claypit Pond	33.1	2.3	5.9	265	49	0.048	68	166
7	Claypit Pond	37.4	2.1	8.3	277	50	0.051	75	176
8	Claypit Pond	38.1	1.1	7.4	100	44	0.040	65	115
10	Outlet Claypit Pond	37.5	0.5	6.4	69	51	0.043	73	104
11	Silver Cr above hwy	21.3	2.4	5.9	98	44	0.044	114	113
12	Silver Cr abv mouth	26.4	3.1	8.1	64	48	0.030	95	110

U = Limit of detection

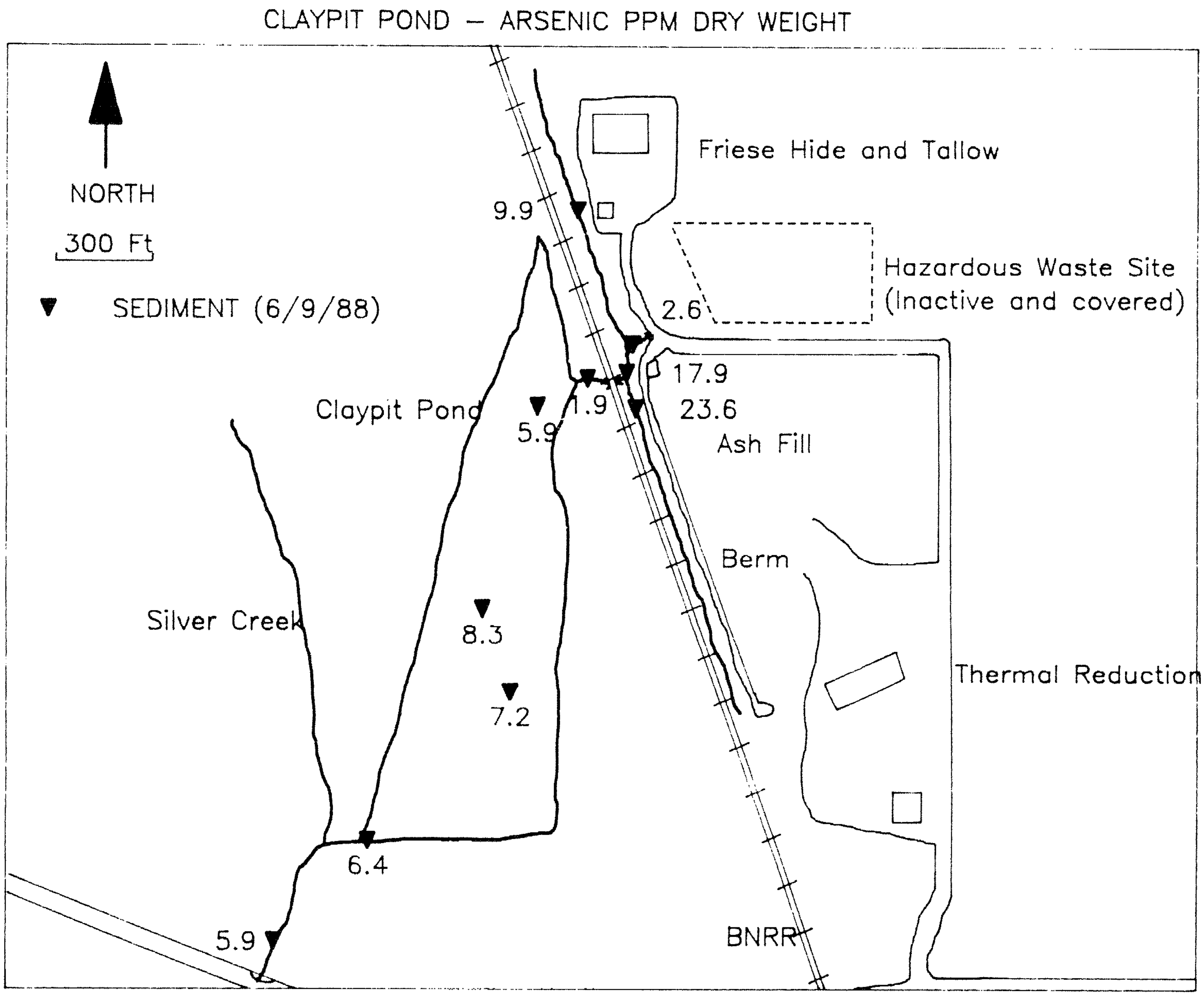


Figure 5. Concentrations of arsenic found in sediments near Claypit Pond.

CLAYPIT POND – CHROMIUM PPM DRY WEIGHT

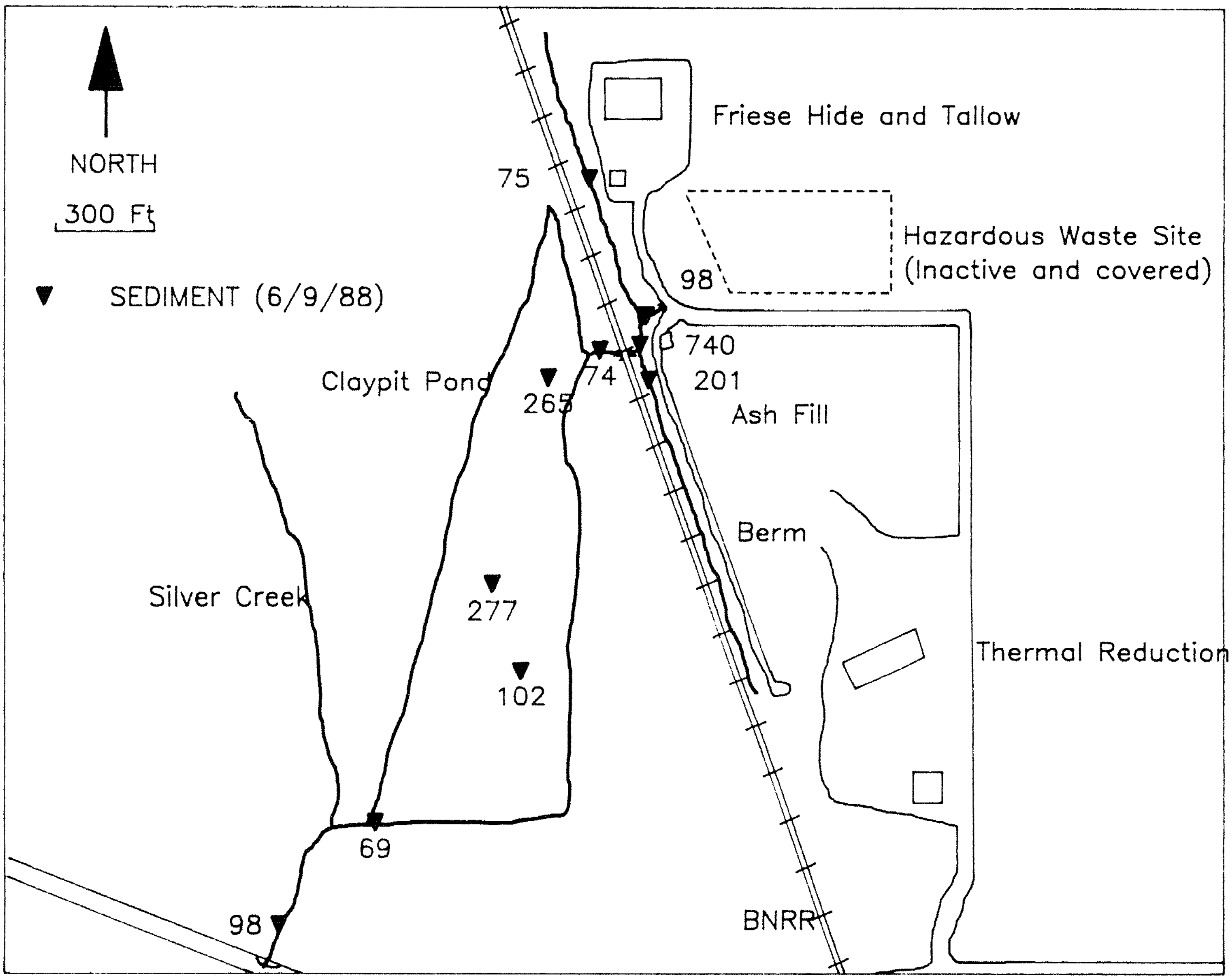


Figure 6. Concentrations of chromium found in sediments near Claypit Pond.

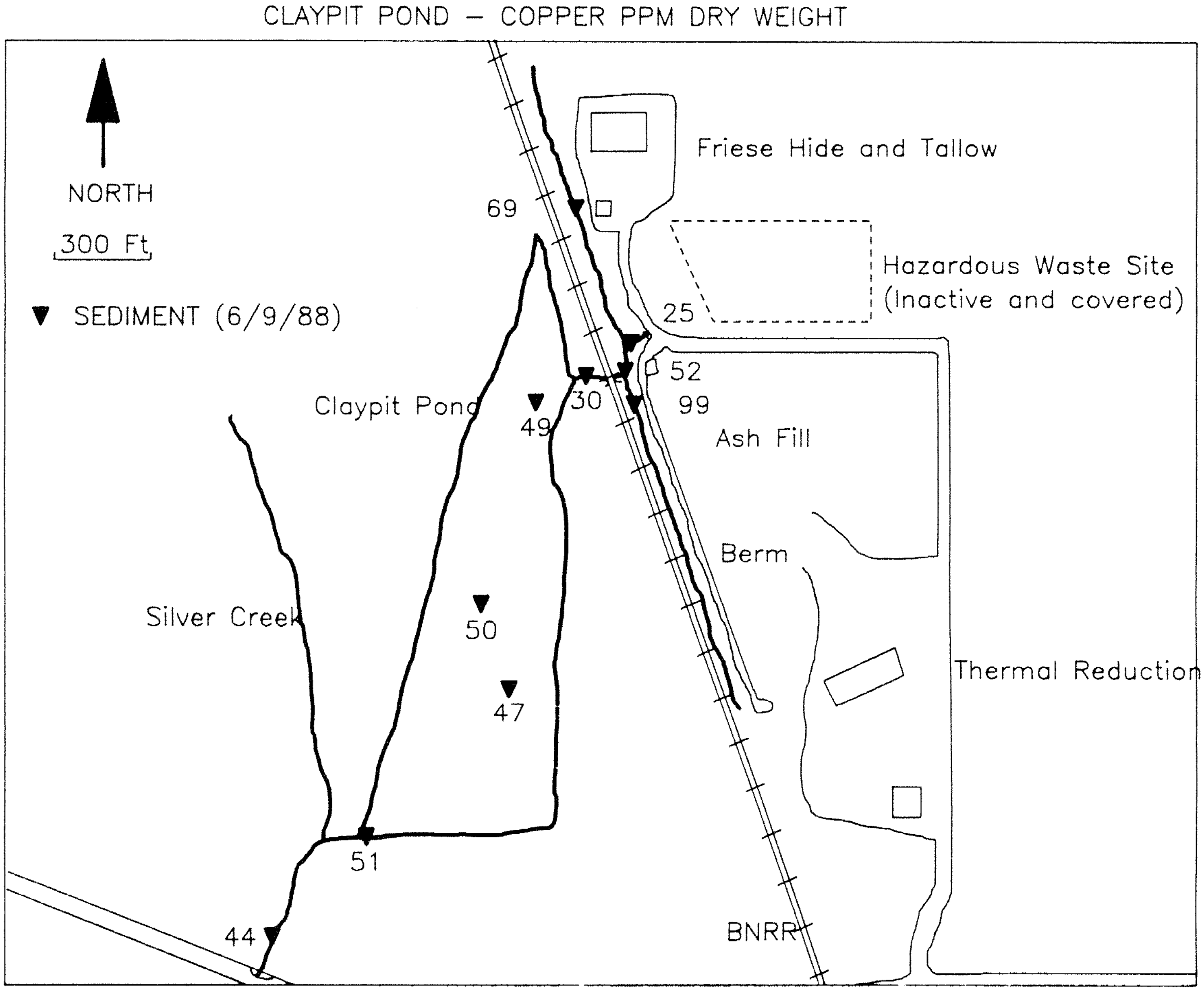


Figure 7. Concentrations of copper found in sediments near Claypit Pond.

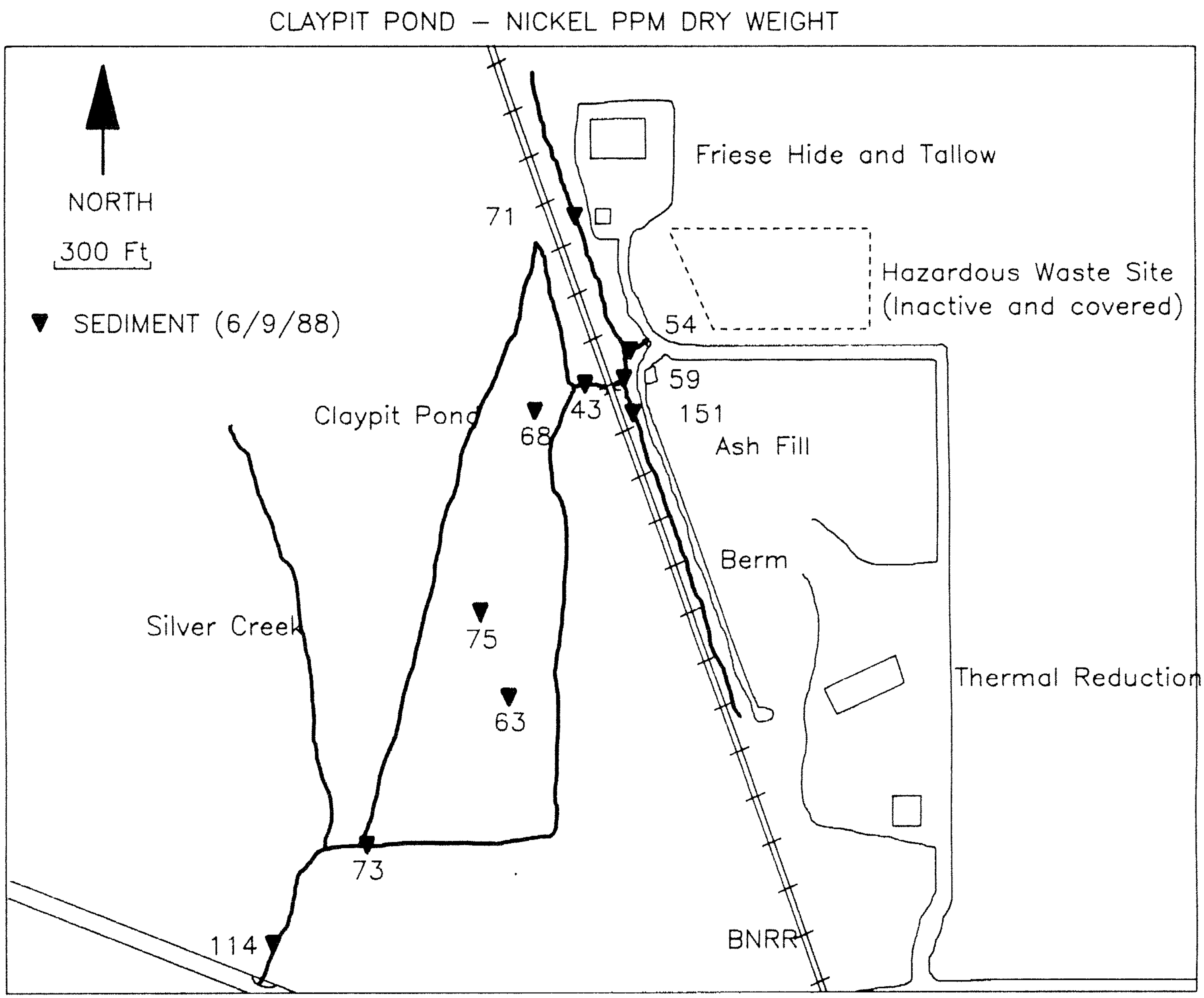


Figure 8. Concentrations of nickel found in sediments near Claypit Pond.

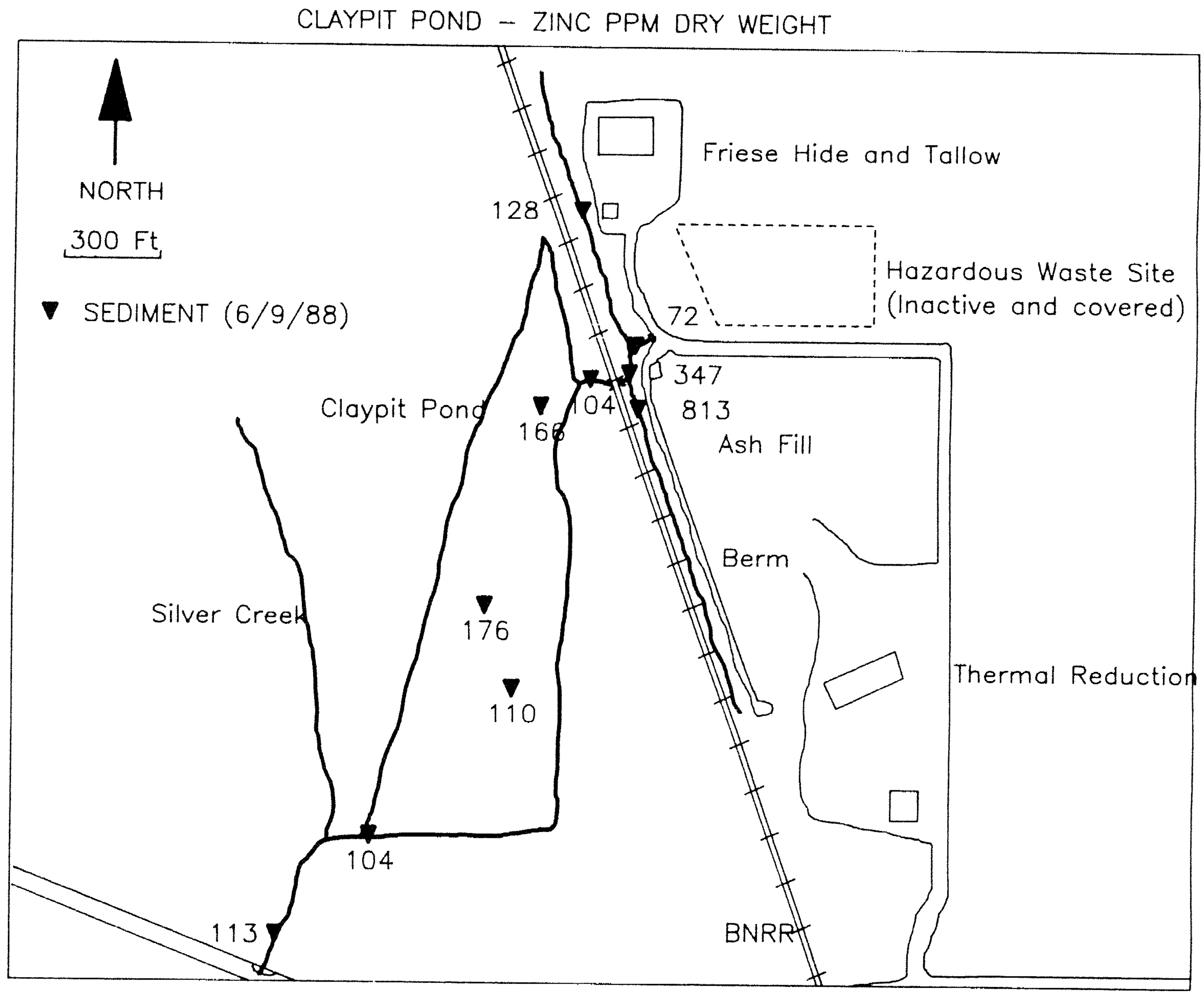


Figure 9. Concentrations of zinc found in sediments near Claypit Pond.

Table 4. Concentrations found in reextraction of sediment samples 3 and 4. Initial analysis performed 15 July 1988 and reanalyzed in December 1988. All concentrations on mg/kg dry weight basis.

	Site 3		Site 4	
Metal	Initial	Reanalysis	Initial	Reanalysis
Cadmium	< 0.5	1.5	< 0.5	5.6
Chromium	740	666	201	195
Copper	52	55.7	99	112
Nickel	59	92.6	151	259
Lead	< 2	< 5	72	< 5
Zinc	347	301	813	778

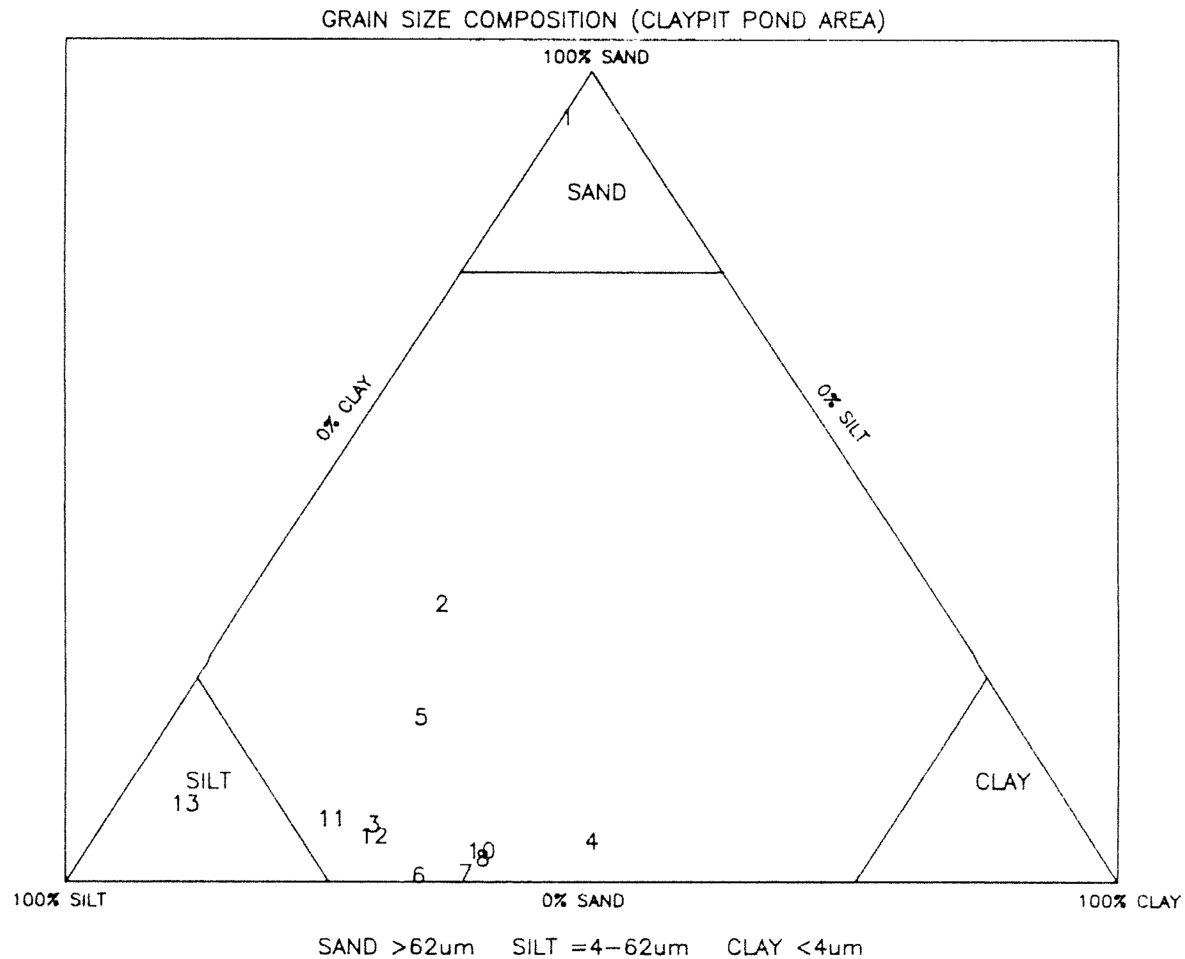


Figure 10. Grain size composition diagram of Claypit Pond-vicinity sediments.

Table 5. Probabilities of correlations between metals concentrations and percent clay (grain size < 4 um) and total organic carbon (TOC) for study sites from this study. Probabilities are compared to samples without two highest values of percent clay and percent TOC. Note the strong effects of the highest two sites.

	%CLAY		%TOC	
	n = 12	(Without 2 highest) n = 10	n = 12	(Without 2 highest) n = 10
As	0.127	0.604	0.000*	0.638
Cr	0.587	0.496	0.082	0.314
Cu	0.034*	0.164	0.006*	0.843
Ni	0.884	0.435	0.153	0.414
Hg	0.151	0.507	0.003*	0.903
Zn	0.068	0.322	0.000*	0.184

* = Significant at $p < 0.05$

Table 6. Percent clay (grain size < 4 um), percent total organic carbon (TOC), and metals concentrations in soil (ug/g dry weight) at study area sites and nearby sites reported in other studies.

Site #	Location	Source	% Clay	% TOC	As	Cr	Cu	Hg	Ni	Zn
ON-SITE										
1	Haz waste drainage	This study	0.4	0.4	2.6	98	25	0.040	54	72
2	Freise Hide & Tallow	This study	18.9	0.6	9.9	75	69	0.035	71	128
3	Confl. before culvert	This study	25.7	6.9	17.9	740	52	0.060	59	347
4	Stream outside berm	This study	47.4	11.0	23.6	201	99	0.067	151	813
5	Stream feeding pond	This study	23.6	1.4	1.9	74	30	0.027	43	104
6	Claypit Pond	This study	33.1	2.3	5.9	265	49	0.048	68	166
7	Claypit Pond	This study	37.4	2.1	8.3	277	50	0.051	75	176
8	Claypit Pond	This study	38.1	1.1	7.4	100	44	0.040	65	115
10	Outlet Claypit Pond	This study	37.5	0.5	6.4	69	51	0.043	73	104
	GEOMETRIC MEAN				7.1	151	48	0.044	69	166
DOWNSTREAM										
11	Silver Cr above highway	This study	21.3	2.4	5.9	98	44	0.044	114	113
12	Silver Cr above mouth	This study	26.4	3.1	8.1	64	48	0.030	95	110
13	Silver Cr mouth	EPA/Lummi 87[1]	6.5	1.3	8.6	86	41	0.043	157	98
E	Silver Creek Mouth	EPA/Lummi 87	3.1	NA[2]	7.5	66	43	0.044	156	82
	GEOMETRIC MEAN				7.5	77	44	0.040	128	100
REFERENCE										
A	Silver Creek tributary	EPA/Lummi 87	10.8	NA	4.1	49	31	0.027	38	83
B	Nooksack R "control"	Ruiz 1988	4.3	0.4	5.2	38	26	NA	109	62
F	Whatcom cr	Kendra 1988	3.1	1.0	3.3	24	22	0.049	27	110
G	Whatcom cr	Kendra 1988	0.7	0.4	3.1	26	13	0.042	21	72
H	Whatcom cr	Kendra 1988	3.4	4.0	6.1	40	47	0.071	35	170
I	Whatcom cr	Kendra 1988	2.2	0.8	4.9	25	12	0.040	23	45
	GEOMETRIC MEAN				4.3	32	23	0.044	35	82

[1]Unpublished data from joint EPA/Lummi Tribe sampling
[2]NA = Not Analyzed

results of statistical analyses by area. On-Site area chromium and copper concentrations are significantly elevated above Reference areas ($p < 0.05$ with Bonferrari corrections for paired testing; Wilkinson, 1988). Levels of chromium at both the On-site and Downstream sites are higher than the Reference areas. Nickel is more abundant in the Downstream sites than at On-site (significant at $p < 0.05$) or Reference (not significant) stations. Finally, percent clay also varies by location with the On-site having higher percent clay than the Reference area. Significant correlations exist between percent clay and arsenic, copper, and zinc ($p < 0.05$) and between percent TOC and arsenic, chromium, copper, mercury, and zinc ($p < 0.05$) for the three areas combined. However, like the study area samples, these correlations falter if the two highest values of percent clay and percent TOC are removed from consideration (see Table 8). Thus possible effects of differences in percent clay and percent TOC are equivocal.

Variations in percent clay and TOC may confound efforts at comparisons of metals concentrations between sites. Because chromium concentrations appear to have the greatest difference between sites and were found at high concentrations in water and sediment, I analyzed relative enrichment of chromium in sediment based on a ratio of chromium concentrations to other metals. Table 9 shows these ratios of chromium on other metals. Four ratios (chromium to arsenic, copper, nickel, zinc) were each ranked by site and the median of the four ranks created a list of sites ranked by relative chromium enrichment against other metals. Note that the rank appears consistent with the hypothesis that the chromium concentrations are highest in the pond and the streams that feed the pond from Thermal Reduction Company's active and inactive waste sites. These overall ranks of chromium enrichment differed by region (Table 10) with the high ratios significantly more prevalent at the On-site area and the lower ratios at the Reference areas outside the watershed of the Claypit Pond area. The reference areas are not control areas in that they are heavily affected by urban stormwater runoff from the city of Bellingham. These ratios are a second way to view relative concentrations and appear consistent with the relative differences of the concentrations themselves.

<u>Other Sites</u> - Studies of heavy metals concentrations--especially chromium--in freshwater sediments from other areas of Western Washington are not prevalent in the literature. However, metals concentrations in freshwater sediments from numerous sites in the U.S. are available from the EPA STORET database. Potentially useful data on concentrations in Western Washington marine bay sediments are available from from the database SEDQUAL (PTI, 1988). Figure 11 shows cumulative frequency distribution of Claypit Pond-vicinity sediments as well as national STORET freshwater sediments and marine sediments in Puget Sound. Note the comparatively high levels of nickel, copper, and chromium. Although possible differences in freshwater and marine chemistry may confound comparisons, these contrasts provide an illustration of the relatively high concentrations of metals in the Claypit Pond vicinity.

Table 7. Comparison of sediment values between Onsite stations, Downstream stations, and Reference stations. Results are probabilities derived through Kruskal Wallace test. Probabilities corrected for between means error with Bonferrari procedure.

Sites	All	Onsite versus Reference	Onsite versus Downstream	Downstream versus Reference
Clay	0.021*	0.042*	0.123	0.110
TOC	0.291	--	--	--
As	0.083	--	--	--
Cr	0.001*	0.003*	0.076	0.033*
Cu	0.020*	0.013*	0.189	0.055
Hg	0.961	--	--	--
Ni	0.005*	0.075	0.014*	0.057
Zn	0.081	--	--	--

* = Significant at $p < 0.05$

Table 8. Probabilities of correlations between metals concentrations and percent clay (grain size < 4 um) and total organic carbon (TOC) for all samples and reference areas. Probabilities are compared to samples without two highest values of percent clay and percent TOC. Note the strong effects of the highest two sites.

	%CLAY		%TOC	
	n=19	(Without 2 highest) n=17	n=19	(Without 2 highest) n=17
TOC	0.064	0.351		
As	0.024*	0.176	0.000*	0.361
Cr	0.153	0.126	0.033*	0.426
Cu	0.001*	0.010*	0.002*	0.203
Ni	0.072	0.266	0.075	0.509
Hg	0.676	0.738	0.003*	0.081
Zn	0.029*	0.131	0.000*	0.011*

* = Significant at $p < 0.05$

Table 9. Relative chromium enrichment (expressed as ratio of chromium to other metals concentrations in sediments)(dry weight) from samples taken near Claypit Pond and other reference areas. Overall Rank Median is median of ranks of sites in high chromium ratios.

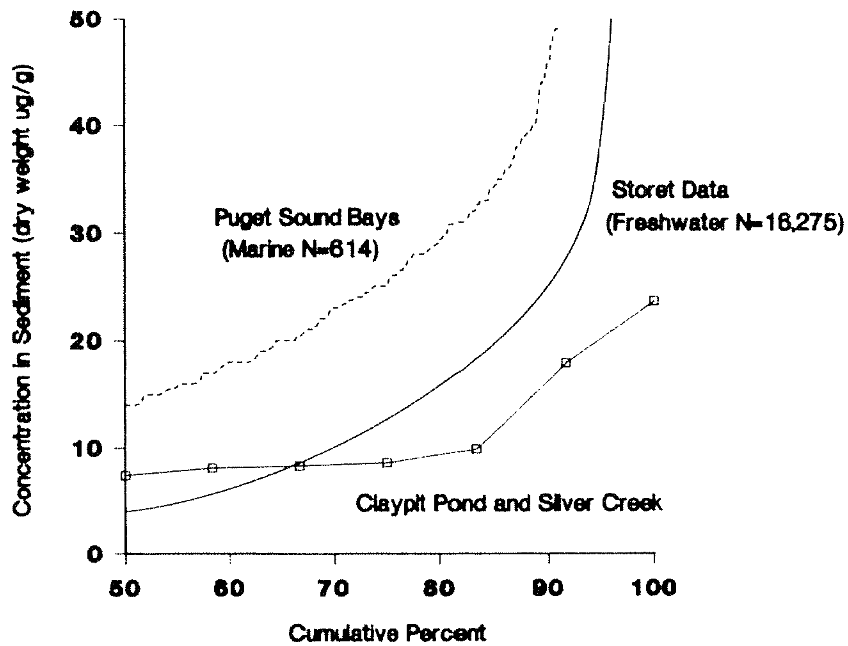
Site #	Location	Type	Cr/As	Cr/Cu	Cr/Ni	Cu/Zn	Rank Cr/As	Rank Cr/Cu	Rank Cr/Ni	Rank Cu/Zn	Overall Rank Median
3	Confl. bfr culvert	Onsite	41.3	14.2	12.5	2.1	2	1	1	1	1.0
6	Claypit Pond	Onsite	44.9	5.4	3.9	1.6	1	3	2	2	2.0
7	Claypit Pond	Onsite	33.4	5.5	3.7	1.6	5	2	3	3	3.0
1	Haz waste drainage	Onsite	37.7	3.9	1.8	1.4	4	4	4	4	4.0
5	Stream feeding pond	Onsite	38.9	2.5	1.7	0.7	3	5	5	9	5.0
8	Claypit Pond	Onsite	13.5	2.3	1.5	0.87	7	6	6	6	6.0
11	Silver Cr. abv hwy	Downstream	16.6	2.2	0.9	0.87	6	7	15	7	7.0
13	Silver Cr. mouth	Downstream	10.0	2.1	0.5	0.88	10	8	17	5	9.0
A	Silver Cr. trib.	Reference	12.0	1.6	1.3	0.59	8	12	8	12	10.0
4	Stream outside berm	Onsite	8.5	2.0	1.3	0.25	12	10	7	17	11.0
10	Outlet Claypit Pond	Onsite	10.8	1.4	0.9	0.66	9	15	13	10	11.5
G	Whatcom Cr.	Reference	8.4	2.0	1.2	0.36	13	11	9	16	12.0
E	Silver Cr. mouth	Downstream	8.8	1.5	0.4	0.80	11	13	18	8	12.0
I	Whatcom Cr.	Reference	5.1	2.1	1.1	0.55	19	9	11	15	13.0
2	Freise Hide & Tallow	Onsite	7.6	1.1	1.1	0.58	15	18	12	13	14.0
12	Silver Cr. abv mouth	Downstream	7.9	1.3	0.7	0.58	14	16	16	14	15.0
B	Nooksack R. "control"	Reference	7.3	1.5	0.3	0.61	17	14	19	11	15.5
F	Whatcom Cr.	Reference	7.3	1.1	0.9	0.22	16	17	14	19	16.5
H	Whatcom Cr.	Reference	6.6	0.9	1.1	0.24	18	19	10	18	18.0

Table 10. Comparison of chromium/other metals ratios between Onsite stations, stations Downstream, and Reference stations. This test eliminates the potential effects of differences in %clay and % total organic carbon. Results are probabilities derived through Kruskal-Wallace test. Probabilities corrected for between means error with Bonferrari procedure.

Sites	All	Onsite versus Reference	Onsite versus Downstream	Downstream versus Reference
Cr/As	0.013*	0.021*	0.495	0.264
Cr/Cu	0.080	--	--	--
Cr/Ni	0.005*	0.075	0.015*	0.264
Cr/Zn	0.023*	0.039*	0.537	0.099
Median	0.014*	0.030*	0.270	0.327

* = Significant at $p < 0.05$

Arsenic



Chromium

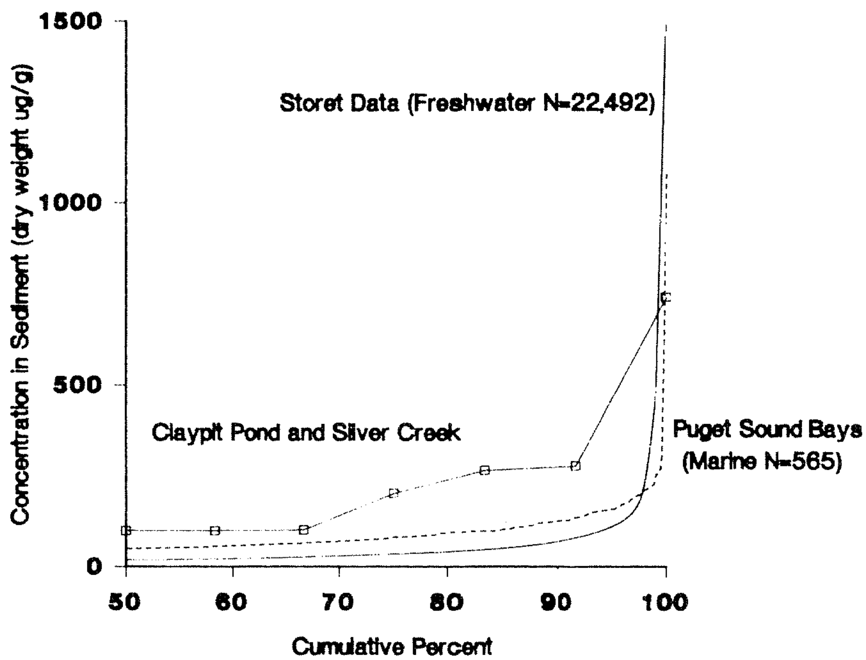
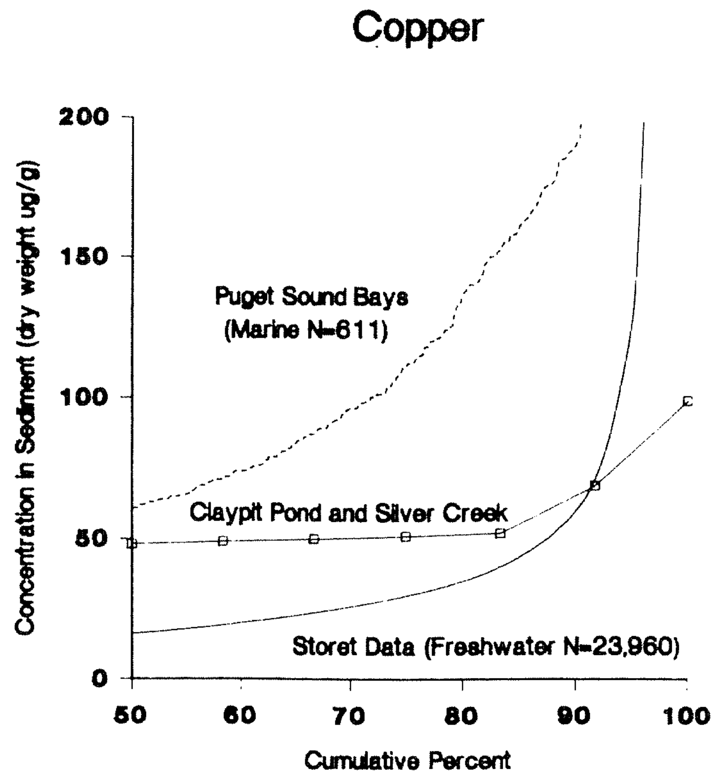


Figure 11. Cumulative frequency distributions of metals concentrations found in the Claypit Pond area in this study (sites 1-13;n = 12), freshwater sediments in USA recorded in EPA STORET database, and marine sediments from Puget Sound recorded in SEDQUAL database. Note that the sample median (50%) from Claypit Pond exceeded the 90th percentile of chromium and nickel concentrations in in the STORET and SEDQUAL databases.



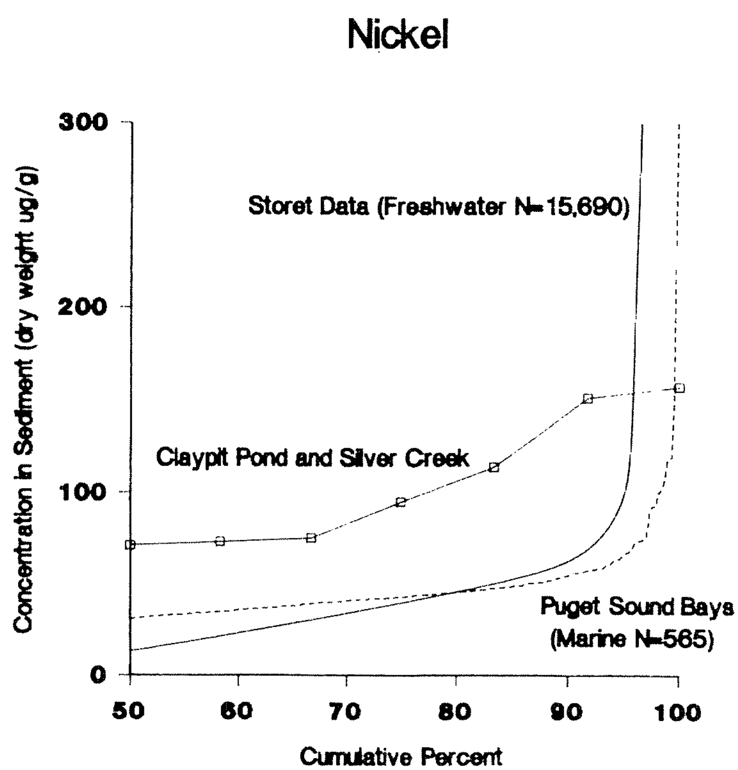


Figure 11 - continued. Cumulative frequency distributions of metals concentrations found in the Claypit Pond area in this study (sites 1-13;n=12), freshwater sediments in USA recorded in EPA STORET database, and marine sediments from Puget Sound recorded in SEDQUAL database. Note that the sample median (50%) from Claypit Pond exceeded the 90th percentile of chromium and nickel concentrations in in the STORET and SEDQUAL databases.

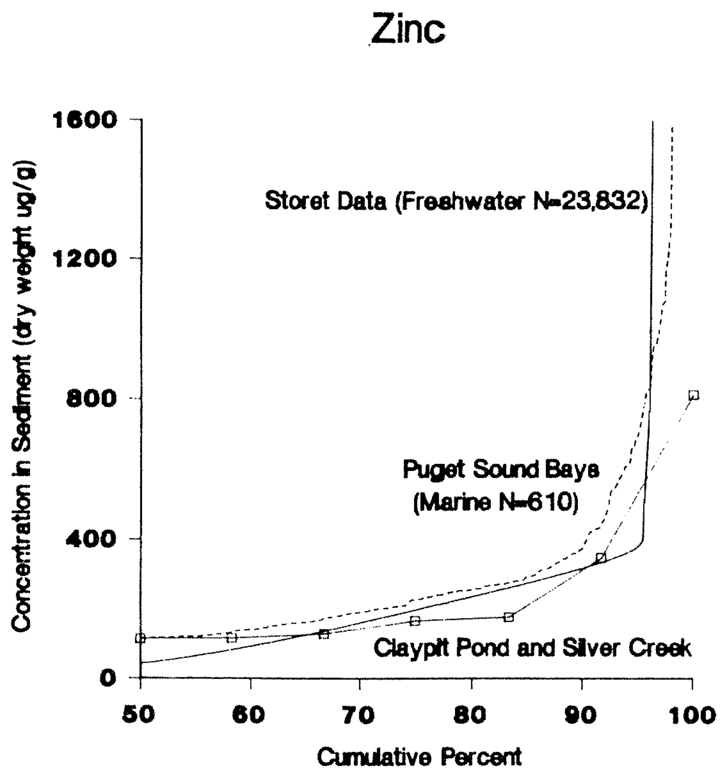


Figure 11 - continued. Cumulative frequency distributions of metals concentrations found in the Claypit Pond area in this study (sites 1-13;n=12), freshwater sediments in USA recorded in EPA STORET database, and marine sediments from Puget Sound recorded in SEDQUAL database. Note that the sample median (50%) from Claypit Pond exceeded the 90th percentile of chromium and nickel concentrations in in the STORET and SEDQUAL databases.

Temporal Trends in Metals Contaminants

Two earlier studies report limited sediment contaminant data at Claypit Pond (Kittle 1980, Douglas 1987). Table 11 compares metals concentrations found in and near Claypit Pond in 1980, 1986, and 1988 (present study). Based on these limited data, the following observations may be made. Arsenic levels in the ditches between TRC and the pond appear higher in 1988 than in 1986. There is no clear temporal pattern for chromium; copper and zinc levels have remained relatively steady with the exception of site 4; and mercury appears to have declined somewhat. The key point here is that with the exception of mercury, the metals concentrations in Claypit Pond area have not declined appreciably since 1980. Variation between 1986 and 1988 may be caused by differences in percent total organic carbon between samples as the 1988 samples (3 and 4) are very high in organic carbon (see discussion above) and the inability to exactly duplicate the sampling location.

Sediment Toxicity and Sediment Criteria

No regulatory criteria for freshwater sediment contamination exist in Washington State. The Wisconsin Department of Natural Resources have developed sediment criteria using a "Background Approach" that is based on levels of metals found in reference areas (Sullivan *et al.*, 1985). These interim criteria make no attempt to define a maximum, biologically safe level of contamination and thus provide a weak legal and biological basis for directing potential mitigation of elevated concentrations in sediments. Nonetheless, these criteria provide one yardstick by which to measure sediment contamination at Claypit Pond. Claypit Pond sediments exceed these interim criteria for chromium and zinc (>125 ug/g). In other words, in-water disposal of Claypit Pond sediments would not be allowed in the Great Lakes bordering Wisconsin.

Another method to assess freshwater sediment toxicity is the triad approach using bioassays, benthic infaunal analysis, and chemical analysis (Yake *et al.*, 1986) which was applied to sediments in Lake Union, Washington. Sediment quality criteria for freshwater sediments may be developed using this method but currently no toxicity criteria exist for freshwater sediments.

Marine sediment criteria can be examined to provide a measure of possible biological effects of contaminated freshwater sediments. Criteria for marine sediments have been developed using data developed using the triad approach and interpreted by the Apparent Effects Threshold (AET) principle (PTI 1988). Simply stated, the AET for a given contaminant is the level above which deleterious biological effects are always seen. These biological effects are measured by four parameters: amphipod, oyster larvae, microtox bacteria bioassays, or benthic species diversity. Through the large data set available for Puget Sound sediments, data from 50 to 200 stations are available to assay AET levels for most priority pollutants. Table 12 reviews the AETs for metals analyzed in this study. Note that three sites exceed the AETs for chromium and one site exceeds the AET for nickel as

Table 11. Comparison of sediment levels between years of similar site locations near Claypit Pond. All values ug/g dry wt.

Location	Site #	Study	Year	As	Cd	Cr	Cu	Pb	Ni	Hg	Zn
Claypit pond (near 6)	-	Kittle 1981	1980	--	--	520	50	29	--	0.160	190
North Claypit	6	This study	1988	5.9	--	265	49	--	68	0.048	166
Claypit pond (near 7)	-	Kittle 1981	1980	--	--	290	47	33	--	0.350	170
Middle Claypit	7	This study	1988	8.3	--	277	50	--	75	0.051	176
Upstream (near to 3)	-	Douglas 1987	1986	2.6	0.6	101	52	15	82	0.100	286
Confluence bfr culv	3	This study	1988	17.9	--	740	52	--	59	0.060	347
Downstream (near to 4)	-	Douglas 1987	1986	6.1	1.7	87	57	34	75	0.050	320
Downstream	4	This study	1988	23.6	--	201	99	--	151	0.067	813

Table 12. Puget Sound AET (Apparent Effects Threshold) concentrations in sediments for metals (ug/g normalized to dry weight) compared to concentrations of metals at onsite areas of Claypit Pond vicinity. (See text for explanation of AET). Source: PTI, 1988

Metal	Amphipod	Oyster	Benthic	Microtox	OnSite Concentration Geometric Mean	OnSite Concentration Range
Arsenic	93	700	57	700	7.1	1.9-23.6
Chromium	270	--	260	--	151	69-740
Copper	1300	390	530	390	48	25- 99
Mercury	2.1	0.59	2.1	0.4	0.044	0.027-0.067
Nickel	>140	--	>140	--	69	43-151
Zinc	960	1600	410	1600	166	72-813

measured by benthic infaunal diversity. Again, due to many differences, comparison of marine sediment criteria with freshwater criteria must be viewed with caution, they nevertheless provide a rough basis of comparison.

CONCLUSIONS

- Metals in waters in the Claypit Pond vicinity have been measured at relatively high concentrations at different sites since 1980. Overall patterns of geographic distribution and temporal variation are not clear.

- Concentrations of copper, chromium, and zinc in sediments in and near Claypit Pond are significantly elevated with respect to nearby reference areas. Chromium levels are some of the highest found in Washington State freshwater and marine sediments. Arsenic may also be moderately elevated although data do not demonstrate a statistical significance.

- Because sediments in the areas draining the TRC facility were, in general, the most contaminated it appears likely that TRC is or was a major source of metals contamination to Claypit Pond.

- Data are inadequate to evaluate temporal changes in sediment metals in these sediments although available data do not suggest major changes over the past eight years.

- Adequate criteria by which to evaluate potential biological effects of contaminated freshwater sediments do not exist. However, if marine sediment criteria are applied to these concentrations, chromium, nickel, and zinc in the sediments exceed levels at which adverse biological effects are expected.

RECOMMENDATIONS

- Sediment bioassays and benthic infaunal diversity studies should be conducted in conjunction with chemical evaluation of these sediments (the "triad" approach) to appraise ecological effects of the high concentrations of metals in Claypit Pond sediments.

- Collect and analyze Claypit Pond sediment cores to evaluate history of metals deposition. This approach may also provide useful information for evaluating whether metals loading to the pond is continuing or has been effectively curtailed.

- Sample and analyze additional sediment to provide better indication of the sources of specific metals to Claypit Pond and the associated drainage.

ACKNOWLEDGMENTS

Several people contributed to the success of this study. Kevin Fitzpatrick requested this study, assisted in field sampling, and reviewed a draft of this report. Steve Twiss at the Washington State Department of Ecology and EPA Manchester laboratory coordinated metals analysis of these sediments. Pam Covey and Roy Araki expedited samples to outside labs (TOC and percent grain size). Bill Yake, Art Johnson, and Will Kendra provided technical consultation and reviewed the manuscript. Carol Perez formatted the final manuscript. I want to thank these people.

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Part 2
Metals Concentrations in Fish Caught in Claypit Pond

INTRODUCTION

This section reports on concentrations in metals found in fish tissue from Claypit Pond and was distributed in essentially the same form as a technical memorandum to Kevin Fitzpatrick dated October 11, 1988. Minor revisions have occurred and this version supersedes that earlier memo. Background on Claypit Pond appears in Part 1 (section on metals in sediments).

METHODS

Sampling Methods

Fish were caught with four 60 ft gill nets each composed of four panels of differing mesh size (.5, 1.0, 1.5, 2.0 inches) set overnight for 20 hours between the 15th and 16th of June. Figure 1 shows the location of Claypit Pond and the gill net sets. All fish were measured and scales or otoliths taken for age determination. A subsample of caught fish was taken for metals analysis. These fish were wrapped in aluminum foil and frozen whole within 8 hours of collection.

Laboratory Methods

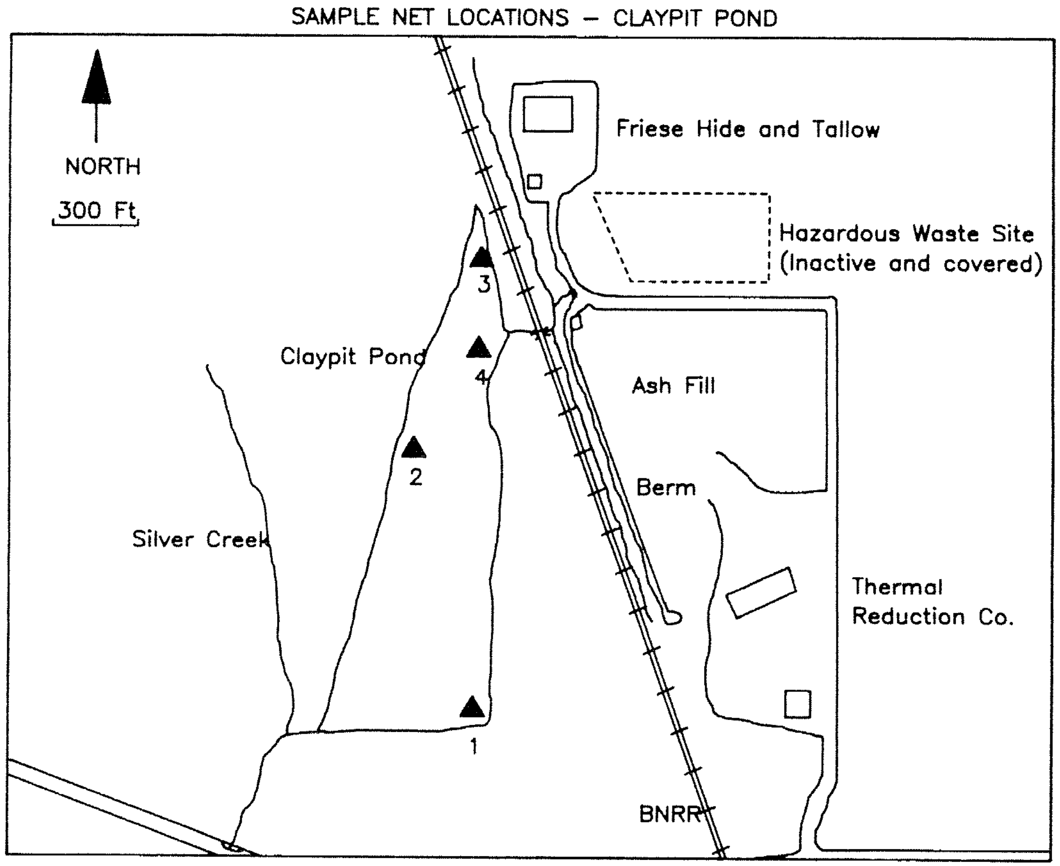
Fish were fileted using acid-rinsed stainless steel knives at the Department of Ecology/EPA Laboratory at Manchester, Washington. Skin was left on the filets. Samples were homogenized in acid-rinsed Waring blenders and stored in pesticide/metals clean glass jars with teflon lid liners (I-Chem series 300, Hayward, California). Samples were analyzed at the Manchester laboratory.

Tissue samples were digested using nitric acid and hydrogen peroxide as specified by EPA Method 3050 (EPA, 1984). All metals except arsenic and mercury were analyzed by EPA Method 200.7 (inductively coupled plasma; EPA, 1983). Arsenic was analyzed by graphite furnace/atomic absorption (EPA Method 206.2) while mercury was analyzed using cold vapor/atomic absorption EPA Method 245.5 (EPA, 1983).

Quality Assurance

To assess precision and accuracy of the analytical methods one sample was homogenized and split. These split duplicates were spiked with the target metals. In addition, reference material (freeze-dried fish) that has been analyzed by 5-7 EPA referee laboratories, was analyzed twice in the same run as these fish samples.

Table 1 reviews tests of precision of analytical methods. Precision was measured using relative percent difference (RPD: the difference between two measurements divided by their mean) of replicate analyses. For the spiked samples, the RPD's are acceptably low for all metals (<35% [based on EPA Contract Lab Program (CLP) requirements for tissues]). However, replicates of reference material show high RPD's for arsenic and copper (nickel has a high RPD but the concentrations reported are near the apparent quantitation limit and thus are not a good measure of RPD). Based on these results, the concentrations of arsenic and copper may be considered estimates and are flagged with a "E".



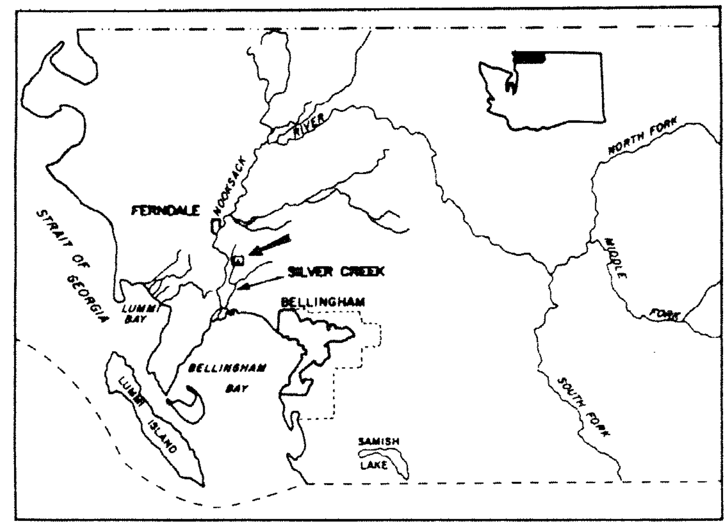


Figure 1. Study area.

Table 1. Measures of accuracy and precision of metals analysis tissue samples.

Type of Measure	Metals - Total							
	As	Cd	Cr	Cu	Hg	Pb	Ni	Zn
Spike								
CP2 Spike recovery %	52	90	92	94	42	88	86	130
CP2 Spike recovery %	42	101	106	98	49	75	94	98
Relative % difference (RPD)	21%	12%	14%	4%	15%	16%	9%	28%
Reference Material								
Reference value[1] ug/g dry	2.43	0.16	0.58	2.21	2.52	0.26	0.54	43.6
95% CI[2] ug/g dry	0.8- 4.1	0.0- 3.2	0.0- 1.3	0.9- 3.4	1.2- 3.8	0.0- 0.6	0.0- 1.1	35 - 51
Reference analysis[3] ug/g dry	1.6	1.0U[4]	2.0U	3.4	1.08X[5]	4.0U	3.9X	48.2
Reference analysis ug/g dry	0.8	1.0U	2.0U	2.3	0.98X	4.0U	2.0U	38.6
Avg recovery	49%	--	--	129%	41%	--	722%	99%
Relative % difference (RPD)	67%	--	--	39%	10%	--	64%	22%

[1] Mean value of reference material (freeze-dried fish) reported by 5-7 referee labs (From EPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio). Concentrations reported as reference are not certified. Reference material prepared in 1981 and not validated since 1984. These reference values may be incorrect.

[2] 95% confidence interval of the population of reference values reported by labs above.

[3] Analysis of reference material conducted in same batch as Claypit Pond fish.

[4] U = Quantitation limit above 95% confidence interval

[5] X = Outside of 95% confidence interval

Results of tests of accuracy are also presented in Table 1. Recovery of metals from spiked samples show acceptable recovery (EPA CLP requires 75 to 125% recovery) for all metals except arsenic and mercury. Arsenic and mercury recoveries were between 41 and 52%. These metals are also flagged with an "E".

The recovery performance from reference material compared to other laboratories' analyses of the same material is more difficult to interpret. The metals concentrations associated with the reference materials were the mean of the values determined through three replicate analyses by 5-7 EPA referee laboratories and the standard deviation of the mean represents the variation in results between these EPA labs. Only after these analyses were made was it discovered that the reference material was last produced in 1981 with the most recent checks made in 1984. EPA warrants the concentrations for a period of two years and has recently removed the material from distribution (pers. comm. Jim Longbottom, EPA Cincinnati). Thus, current concentrations in reference materials may differ from earlier values obtained from EPA referee laboratories. The extent of this possible variation is unknown.

During the present study, analyses of the reference samples showed only copper and zinc falling within the 95% confidence interval on both replicate analyses. Analytical accuracy for cadmium, chromium, and lead could not be calculated from these analyses because reference sample concentrations were below the Manchester Laboratory's reported detection limits for these metals. Arsenic was within these bounds on one of two replicates. Note the recovery of mercury and arsenic in the spiked samples is very similar to the recovery concentrations in the reference materials. Thus, the lab methods used at Manchester Laboratory recovered a fairly consistent 40-50% of arsenic and mercury in the samples. Concentrations reported here have not been corrected for these recoveries.

RESULTS AND DISCUSSION

Metals Concentrations in Fish

Fish caught with 4 gill nets and composited for analysis are summarized in Table 2. The predominant fish caught was yellow perch (Perca flavescens). Two samples were composited from these fish, one composed of whole bodies of subadults and the other filets of adult fish. Whole fish were analyzed to give an indication of overall contamination in all tissues (including muscle) as well as to provide a comparison to literature values that often report whole fish concentrations. Filets from cutthroat trout (Salmo clarkii) also were composited into one sample. All filet samples (with skin attached) were taken primarily to assess possible adverse health effects of consumption of fish caught in Claypit Pond.

Concentrations of metals (As, Cd, Cr, Cu, Hg, Pb, Ni, Zn) found in the four fish samples are shown in Table 3. All concentrations are reported on a wet weight basis. Neither cadmium nor lead was detected. With the exception of arsenic, the cutthroat had lower metals concentrations than the other samples. These cutthroat were sea-run and may reflect exposure from other habitats (marine waters). The resident catfish presumably is exposed to the highest concentrations of contaminants near the sediments owing to its near-benthic habitat. The

Table 2. Weight and length of fish taken from Claypit Pond, June 15-16, 1988, for heavy metals analysis.

Net #1	Species	Weight (gm)	Fork Length (cm)	Sample No.	Sample Tissue
1	*S. clarkii*	148.5	22.5	CC3	Filet
1	*S. clarkii*	221.2	24.0	CC3	Filet
2	*S. clarkii*	621.0	36.5	CC3	Filet
3	*P. flavescens*	34.9	12.0	CP2	Whole fish
3	*P. flavescens*	44.0	14.0	CP2	Whole fish
4	*P. flavescens*	42.0	13.0	CP2	Whole fish
4	*P. flavescens*	55.9	15.0	CP2	Whole fish
4	*P. flavescens*	34.9	13.5	CP2	Whole fish
4	*P. flavescens*	217.2	21.0	CP1	Filet
4	*P. flavescens*	135.8	19.0	CP1	Filet
4	*P. flavescens*	137.8	18.0	CP1	Filet
4	*P. flavescens*	109.6	17.5	CP1	Filet
3	*I. nebulosus*	531.1	30.5	F4	Filet

S. clarkii = cutthroat trout,
P. flavescens = yellow perch,
I. nebulosus = brown bullhead.

Position 1 on south shore,
2 on middle western shore,
3 on northernmost shore,
4 on 3/4 up north on east shore just off inlet.

Table 3. Metals concentrations in fish caught in Claypit Pond. All values ug/g wet weight basis.

Sample #	Fish	Tissue	Metals - Total							
			As	Cd	Cr	Cu	Hg	Pb	Ni	Zn
CP1	Perch	filet	0.04UE	0.1U	0.8	1.6E	0.064E	0.4U	1.7	13.2
CC3	Cutthroat	filet	0.40E	0.1U	0.3	0.7E	0.049E	0.4U	0.9	4.0
F4	Catfish	filet	0.52E	0.1U	0.2U	0.8E	0.034E	0.4U	3.5	5.7
CP2	Perch	whole	0.12E	0.1U	1.0	2.1E	0.058E	0.4U	1.2	11.5

U = Detection limit (contaminant not found at or above this concentration)

E = Considered estimate because quality control bounds were exceeded (see text for complete explanation).

concentrations of nickel and arsenic were highest in catfish. However with these small sample sizes, little significance can be placed on differences between species.

Comparison of Concentrations in Fish

Table 4 compares concentrations of selected metals found in whole yellow perch in several river systems in Washington and California. Concentrations found in Claypit Pond fish do not appear elevated above fish tissue from these other drainages. Unfortunately, the studies referenced in this table (Lowe et al., 1985, and May and McKinney, 1981) did not include nickel and chromium analyses. Table 5 shows the concentrations of mercury found in yellow perch in 1980 and in 1988 in Claypit Pond. Although the concentrations appear to have increased since 1980, the sample size is too small to appraise significance. Mercury concentrations in both years appear low.

Table 6 shows concentrations of metals in freshwater fish reviewed by Moore and Ramamoorthy (1984). The concentrations found in Claypit Pond fish generally fall below concentrations that these authors characterize as high. Chromium, copper, and arsenic may be slightly elevated in several tissue samples. Interpretation of the arsenic concentration in the cutthroat trout is somewhat difficult as these fish were sea-run and marine fishes often show naturally elevated arsenic concentrations: e.g., Johnson (1988) found 0.6 to 0.9 ug/g arsenic (wet weight) in the muscle of Atlantic salmon near Port Townsend, Washington. The levels of chromium and copper may also be marginally elevated. The chromium result is consistent with the high levels of chromium found in the sediment of Claypit Pond and is reviewed in Part 1 of this report.

Legal Limits of Metals Contamination

One of the major concerns that originated this study was the possible threat to human health posed by consumption of fish caught in Claypit Pond. Table 7 shows legal limits of metals for USFDA and Canada as well as median limits from other countries reported by Nauen (1983). The FDA only regulates mercury concentrations in fish.

The FDA limit is for methylmercury, is set at 1.0 ug/g and represents a judgement by FDA to balance the potential risk of consumption against economic considerations. This FDA "action level" is the threshold above which a product can be removed from market. Some states (e.g., Wisconsin and California) have adopted 0.5 ug/g as a guideline for health advisories in consumption of sport fish based on potential adverse effects on pregnant women and their fetuses, children, and people consuming fish at a higher rate than assumed by the FDA (Wisconsin: Anderson and Olson 1986, California: Stratton et al., 1987). FDA formerly had an action level of 0.5 ug/g, but raised it to 1.0 in 1979 (FDA 1979). Johnson et al., (1988) suggests the FDA faces a regulatory problem at the 0.5 ug/g level because some commercial species commonly exceed this concentration.

Table 7 shows none of the concentrations in Claypit Pond fish exceed limits posted by the Canadian or US governments. If mercury concentrations in Claypit Pond fish are corrected for consistent analytical recovery problems noted earlier, then the concentrations in all

Table 4. Comparison of metals concentrations found in whole yellow perch (*Perca flavescens*) in Washington and California. Concentrations are ug/g wet weight.

Location	Year	N	Length (avg) cm	As	Cd	Cu	Hg	Pb	Zn
Columbia, Pasco	1980	1	7.3	0.05	0.01	0.5	0.030	0.1	22.1
Columbia, Pasco	1978	1	7.6	0.05	0.01	0.6	0.040	0.1	26.1
Grand Coulee	1978	1	9.3	0.05	0.07	0.3	0.050	0.1	28.5
Grand Coulee	1976	5	20.1	< 0.25	< 0.05	-	0.030	0.2	-
Klamath River	1981	1	7.8	0.05	0.01	0.3	0.120	0.1	17.9
Klamath River	1976	5	23.4	< 0.05	< 0.01	-	0.090	< 0.1	-
Claypit pond	1988	5	13.5	0.12	< 0.10	2.1	0.058	< 0.4	11.5

1978 and 1980 data from Lowe *et al.*, 1985
1976 data from May and McKinney (1981)

"<" = less than

Table 5. Comparison of concentrations of mercury in whole perch caught in Claypit Pond (ug/g wet weight)

Year	Sample #	Hg	Reference
1980	80-6-466	0.030	Kittle 1980
1980	80-6-467	0.025	Kittle 1980
1980	80-6-468	0.022	Kittle 1980
1988	CP2	0.058	This study, 1988

Table 6. Summaries of literature review on concentrations of metals in fish by Moore and Ramamoorthy (1984). All concentrations wet weight in muscle or whole body.

Metal	"High level"[1] ug/g	"Low level"[2] ug/g	Tissue[3]	Claypit Pond ug/g	Comment
As	0.5-2.0	< 0.1-0.4	W	< 0.04-0.52	Toxic inorganic forms converted in fish to easily excretable organic forms; depuration rapid
Cd	2.5	< 0.5	M	< 0.1	Accumulates in organs, not generally in muscle.
Cr	1-1.7	< 0.25	M	< 0.2-1.0	Residues decline with age, rapid elimination
Cu	2-6	< 1.0	M	0.7-2.1	May accumulate with age in liver
Pb	> 0.7	< 0.7	M	< 0.4	No variation in tissues
Hg	1-3	< 1	W	0.03-0.06	Consumption limits assume all in methylated form
Ni	9.5-13.6	< 1	W	0.9-3.5	Slightly higher in organs than muscle
Zn	16-100	< 3-9	M	4.0-13.2	Concentrates in organs.

[1] "High level" = Cited by Moore and Ramamoorthy (1984) as high concentration usually found near industrial areas
[2] "Low level" = Cited by Moore and Ramamoorthy (1984) as typical or common concentration found away from industrial areas.
[3] Tissue = Basis for "high level" determination. W: whole body basis, M: muscle basis.

Table 7. Legal limits for metals concentrations in fish sold commercially for human consumption compared to levels found in Claypit Pond fish muscle. Units - ug/g wet wt.

	Hg	As	Pb	Cu	Cd	Zn
USFDA "Action Level"	1.0	--	--	--	--	--
Canadian limits	0.5	3.5	0.5	--	--	--
Median International Legal Limits	0.5	1.5	2.0	20	0.3	45
Claypit Pond fish	0.03-0.06	< 0.04-0.52	< 0.4	0.7-1.6	< 0.1	4.0-13

samples are at least an order of 3 lower than limits in Canada, Wisconsin, and California. Canada's limit for arsenic is 3.5 ug/g, a concentration again about three times higher than the highest similarly corrected value for Claypit Pond fish. The limit for lead in Canada is 0.5 ug/g and no lead was found in any samples at the 0.4 ug/g detection limit. Thus the concentrations of regulated metals in fish in Claypit Pond are below legal limits set by the US and Canada and below the median limits for up to 29 countries reviewed by Nauen (1983).

SUMMARY AND CONCLUSIONS

- The laboratory consistently recovered 41-52% of the known amounts of mercury and arsenic. Recoveries of spike concentrations in other metals were acceptable. Recoveries of concentrations in a reference material were variable, in part, possibly owing to the age of the reference material.

- Concentrations of mercury in fish caught in Claypit Pond were below legal limits for the USA and Canada. Arsenic and lead concentrations in fish were below limits posted by Canada. When these concentrations were corrected for recovery they are still all below legal limits for fish. Thus if legal limits of Canada, the US and advisory limits from California and Wisconsin are the criteria for delineating health risk then fish at Claypit Pond apparently pose no significant health risk from elevated levels of metals examined in this study.

- Other metals concentrations in fish are comparable to those found in fish at other sites except for copper, which appears slightly elevated in Claypit Pond fish.

- The metals with the greatest potential for bioaccumulation are mercury and cadmium. Mercury concentrations were low and cadmium was below the detection limit (0.1 ug/g).

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